Examining Rate Priming on Information Processing

A Senior Thesis

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by

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Abstract

The current study investigated the effect of a musical prime on reading rate, reading comprehension, and processing speed. This research also examined if there is a relation between reading speed and reading comprehension. Music and language primes have been shown to affect processing speed similarly, such that when participants were exposed to a slow prime, language production would slow down, and vice versa for fast primes (Jungers, Hupp, & Dickerson, 2016). This result has also been found in other cognitive capacities when participants are exposed to a prime, such as decision-making (Buelow, Hupp, Porter & Coleman, 2016), suggesting that the rate of prime could change processing speed across domains. The current study was looking to further support this theory by testing for processing speed in motor movements and reading rate. Participants completed the Purdue Pegboard Task and The Nelson Denny Reading Test after being exposed to 3 minutes of a classical music prime. The musical prime was manipulated to have both slow and fast tempos. The current study shows that there is a positive correlation between reading rate and reading comprehension, but the rate of prime did not affect processing speed, reading rate, or reading comprehension.

keywords: rate priming, reading comprehension, reading rate, processing speed

Examining Rate Priming on Information Processing

On the typical college campus today, students can frequently be seen with a pair of headphones on listening to their favorite music. They may be walking to class or walking to their dorm, but do they ever think how this can affect their processing of information? According to previous research, when a person is exposed to a fast prime, they tend to have faster cognitive functions, and the opposite is shown when a person is exposed to a slow prime (Buelow, Hupp, Porter, & Coleman, 2016; Jungers & Hupp, 2009; Jungers, Hupp, & Dickerson, 2016). A prime is a stimulus, such as music or speech, that a participant is exposed to before the experiment or task at hand. If this is applied to music, we should see that participants exposed to fast music will process information faster, and those exposed to slow music will process information more slowly. This leads to asking if college students can better comprehend a textbook or a lecture if they listen to fast music before class. The current research investigates if the rate of a music prime can affect processing speed, reading rate, and reading comprehension.

Effect of Rate Priming on Cognition

Previous research has shown an effect of rate priming on different cognitive domains, such as language production, processing speed, and decision making. In a previous study, researchers found that participants would produce speech differently based on the speed of a prime (Jungers et al., 2016). In the study, there were two separate experiments: one with the prime being speech, and the other with the prime being music. In the first experiment, participants would look at a picture that was being described slowly (60 beats per minute) or fast (120 beats per minute). Next, the participants would see another picture, and the participant would describe it. When exposed to a fast language prime, participants spoke faster than when exposed to the slow prime.

Not only do language primes affect speech production, but music primes do as well. In the second study, Jungers et al. (2016) did the same procedure but with familiar musical melodies as primes. Participants were shown the title of the song while listening to it at a slow (60 BPM) or fast (120 BPM) pace. After each song, participants were shown a picture, and they had to describe the picture. Once again, when exposed to the fast prime, participants spoke faster than when exposed to the slow prime. These same findings were replicated using unfamiliar musical melodies (Jungers & Hupp, under review). This research shows that both music and language primes affected how fast the participants described the pictures, specifically showing that when exposed to a fast prime, participants spoke faster than when exposed to a slow prime. This could suggest that there is a common temporal processing mechanism between music and language, or even domain generality of temporal processing.

In a recent study, researchers measured how speech rate affected performance on a decision making task (Buelow et al., 2016). Participants listened to a story recorded at a slow pace (145 seconds long) or fast pace (98 seconds long), and the control group did not listen to a story. Participants then completed the Hungry Donkey Task (HDT), which is an adaptation of the Iowa Gambling Task (IGT), to measure risky decision making. The researchers found that when participants were exposed to a slow language prime, they took longer and made more advantageous decisions on the HDT than those in the fast-prime group, thus, showing that slow language primes led to slower cognitive functions.

In addition to the effect of the rate of primes on language production and decision making, rate of musical prime also affects processing speed. A study conducted by Ilie and Thompson (2011) looked at the relationship between music and processing speed. Their first experiment looked at how exposure to music affected emotion, processing speed, and creativity.

For their first experiment, they manipulated the music to have different pitches (high or low), different rates (fast or slow), and different intensities (loud or soft). To measure processing speed, they had participants complete a routine task after being exposed to 7 minutes of the manipulated classical piece, which consisted of participants identifying wingdings (i.e., arrow or tear-drop) from a one-page document. Ilie and Thompson (2011) found that those who were exposed to the slow music before the routine task took longer on this task than those exposed to the fast music. However, the rate of prime was confounded with their other variables: emotion and arousal. The current study expands this by investigating if the rate of music prime extends to other measures of processing speed, to see if the effects generalize to other cognitive domains such as those used in reading, and to isolate the effect of rate of prime.

Reading Rate and Comprehension

For some, reading comes easy allowing them to process the information faster, but for others, it can be a tough task, and they tend to process information at a much slower pace (LaBerge & Samuels, 1974). Skilled readers have better word recognition, which leads to using less attentional resources (Jenkins, Fuchs, van de Broek, Espin, & Deno 2003). Attentional resources can then be dedicated to comprehension of a text, leading to better comprehension, where in contrast, less skilled readers attend more to word recognition, leading to poor comprehension (Jenkins et al. 2003). In several studies, researchers have looked at how reading rate can affect comprehension, and some have indicated that there is a correlation between natural reading speed and the comprehension of a text. Previous research measured reading rate and reading comprehension in sixth and seventh graders, and found similar results (Hale, Skinner, Wilhoit, Ciancio, & Morrow 2012). Skilled readers have to exert less effort into reading and read faster than less skilled readers, who tend to read slower, tend to also read less often because it requires more effort (Hale et al., 2012).

Breznitz, DeMarco, Shammi, and Hakerem (2001) looked at how reading speed affected adults' comprehension of a text by manipulating how fast participants read. Their participants started with 17 passages from the Test of English as a Foreign Language (TOEFL), which they read at their own speed. When each passage was done, there was a comprehension question following the passage. The test was conducted electronically, allowing for the participants' reading time to be calculated. After the self-paced portion was complete, researchers calculated the individuals' fast-paced reading speed based off the passages that participants comprehended particularly well. To manipulate the fast-paced speed, researchers based the new speed on the individuals' normal reading rate. To force the fast pace on the reading passages, words would disappear individually from the beginning passage until it was complete, and then the comprehension question would appear. Breznitz et al. (2001) found that when participants' reading rate was manipulated to be faster by 12%, their comprehension scores could increase up to 21.8%. One possible explanation is that faster reading speed allows the working memory (WM) to be used more efficiently (Breznitz & Share, 1992). WM is a form of memory that is used when completing demanding tasks, allowing pieces of information to be stored temporarily (Baddeley & Hitch, 1974), and has been found to be an important predictor of reading comprehension (Seigneuric, Ehrlich, Oakhill & Yuill, 2000). WM has a limited amount of resources to be used to maintain information (Baddeley & Hitch, 1974), which could suggest that Breznitz and Share's (1992) theory could be on the right track. Because WM is only able to hold a limited amount of information, reading faster may allow subjects to remember more in that short period of time. If reading speed can be manipulated by a rate prime, it may be able to influence how much information participants can remember.

Music's Effects on Cognition

Background music has been shown to influence processing; music affects concurrent processing in certain areas (Bottroli, Rosi, Russo, Vecchi, & Cavallini, 2014). Background music can have both positive and negative effects on cognition, depending on the task. For example, fast music can lead a participant to take less time on a processing speed task (Bottiroli, Rosi, Russo, Vecchi, & Cavallini, 2014; Ilie & Thompson, 2011). In recent research, it has been found that background music can have a positive effect on the Symbol Digit Modalities Test (SDMT), a processing speed task when compared to no music and white noise groups (Bottiroli et al., 2014). Participants' declarative memory (semantic and episodic) and processing speed were assessed with concurrent background music (Mozart or Mahler), white noise, or neither. Participants in the background music condition showed higher scores on both memory tasks; those in the background music condition with Mozart had higher scores on the SDMT than those in the white noise and no music groups (Bottiroli et al., 2014). Researchers state that music that puts participants in an alert mood and state (i.e., fast music) can produce better scores on processing speed tasks (Bottiroli et al., 2014).

The effect of background music has also been investigated with reading speed. When listening to concurrent background music, reading speed can imitate the speed of the music playing. Kallinen (2002) had participants silently read a news article on their smart-device (such as a phone, or small tablet) while listening to music. Researchers measured how long it took participants to read the article in seconds, but did not measure the specific reading rate.

Participants in a slow music group took a lot longer to read the article than participants in the fast group.

These previous research studies mostly investigate the effect background music has on different tasks, and lacks in research on the effects of music primes (i.e., music played before continuing onto a different task). However, music primes have been shown to affect processing speed (Ilie & Thompson 2011), language production (Jungers & Hupp, 2009; Jungers et al., 2016), and emotional processing (Ilie & Thompson, 2011). The current research is investigating generality of the effect by investigating if a music prime affects processing speed, reading speed, and reading comprehension. Looking at how music primes affect processing will help us understand temporal processing more generally.

Current Study

The current study presents the question: how does the speed of a musical prime affect processing speed, speed of reading, and reading comprehension? First, the Nelson Denny Reading Test (NDRT; Brown, Fishco, & Hanna, 1929) was used to measure reading comprehension and reading speed. The second test that was used was the Purdue Pegboard Task (PPT; Tiffin, 1968) that measures general processing speed. The PPT involves putting pegs into a large board with two parallel rows of holes for the pegs to fit in, and it has been successfully used to measure processing speed across a variety of studies (Marczinski et al, 2012).

It is predicted that those who are exposed to a slow musical prime should process information more slowly and be slower on the PPT and NDRT tasks, compared those who are exposed to a fast musical prime, who are predicted to process information faster. As for reading comprehension, it is predicted that those who are exposed to the fast musical prime will have a higher score on the comprehension portion since they may be able to process the information faster, when compared to those exposed to the slow music prime.

Method

Participants

This study's final analysis included 96 college-age participants from a regional campus of a large Midwestern university enrolled in introductory psychology courses, and received course credit for participating in this study. There were 47 males and 49 females with a mean age of 19.28 years (*SD* = 2.17). There was an approximate equal number of participants across rate priming conditions: slow *n* = 30, fast *n* = 32, control *n* = 34. The participants were predominately white (76.04%), African-American (15.63%), or multi-racial (4.17%). Thirty-one participants were not included in the data analysis who indicated on their demographics sheet that they had serious mental or medical conditions (*n* = 2), if English was not their first language (*n* = 11), or had any untreated vision, hearing, or attention impairments (*n* = 12). Two participants were excluded due to incomplete testing. Participants who appeared to be aware of the experimental manipulation were also excluded from the analyses (*n* = 8), this was determined by what the participant thought the study was for, signaled by the question "What was the purpose of this study" on the demographics sheet.

Procedure and Measures

This research was approved by the university's Institutional Review Board. Participants volunteered through Sona, an online system that allows students to sign up for research studies as part of the requirement for their introductory psychology course. Once they were in the lab, the participants gave informed consent electronically. Participants were then randomly assigned to one of three groups: fast prime (music at 120 BPM), slow prime (music at 60 BPM), and control group (no musical prime). Participants in the two experimental groups were exposed to 3 minutes of music, Serenade No. 4 in D Major ‘Colloredo’, K. 203: VI Andante by Wolfgang Amadeus Mozart, on the computer through headphones at either a fast or a slow pace. The control group went directly into the first task assigned. The music selection could easily be manipulated through Audacity to have both a fast and slow pace, while still having the same pitch, tone, and volume. It was a classical piece without words to ensure the prime remains non-linguistic, which is similar to what the Ilie and Thompson (2011) study used. After the musical prime, participants completed the NDRT to measure reading speed and comprehension and the PPT to measure processing speed. Task order was counterbalanced; half of the participants completed the NDRT first and then the PPT, and the other half completed the tasks in the opposite order.

The NDRT was originally written by Brown, Fishco, and Hanna in 1929, and measures vocabulary, reading rate, and reading comprehension. For the purpose of this study, we used only the reading rate and reading comprehension portion of the test in forms G and H, the most recent forms. The test is completed with a provided answer sheet, reading booklet, and pencil. The comprehension portion consists of 7 reading passages and 38 multiple choice questions, with 5 answer choices each. The first passage of the test contains over 600 words, which allows the researcher to measure reading speed; the rest of the passages are no longer than 3 paragraphs, or around 200 to 300 words. The test is limited to 20 minutes, using the first minute to measure reading rate. Participants start reading the passage and when a minute passes, the experimenter says, “Time,” and the participant recorded what line they reached in the reading passage and then continued reading. Comprehension is scored based on the number of questions the participant answers correctly; it is the number of questions they got right out of 38, multiplied by two to be consistent with typical scoring procedures (Brown, Fishco, & Hanna, 1929).

The second task is the PPT (Tiffin, 1968) used to measure processing speed. It is a board that has two parallel rows with 25 holes each. Pegs are placed in the top of the board in four divots, or bowl-like shapes. Participants are instructed to use their right hand first to put as many pegs in the board on the corresponding side in a 30-second time period. Participants must keep their other hand to the side as they place pegs in the board. The participant then does the same with the left hand, and then both hands at the same time (entering pegs in holes adjacent to each other at the same time). The score is a raw score based on the number of pegs they put in the board. A high score represents faster processing speed (Lafayette Instrument Company, 2015).

When the PPT and NDRT were complete, the participant then completed a paper and pencil demographics form (Appendix A) and was debriefed, as well as received Sona credit and a piece of candy for participation.

Results

Each participant had three scores: PPT, NDRT rate, and NDRT comprehension. The score on the PPT is the total number of pegs placed on the board added across left hand, right hand, and both hand trials. A higher score indicates faster processing speed. The score for the NDRT reading rate is based off the line of the reading passage the participant reaches at the end of the first minute. A higher score indicates faster reading rate. The comprehension portion of the NDRT is based off the number of questions a participant has answered correctly (out of 38) and is multiplied by two. The score is multiplied by two to maintain scoring consistency with previous research. A higher score indicates higher levels of reading comprehension.

A series of one-way ANOVAs were conducted to analyze the effect of musical rate prime on the PPT and NDRT across the three Music Prime Conditions (control, slow, and fast). In addition, a correlation between reading rate and comprehension was calculated for all participants, and one sample t-tests were conducted to determine similarity with normative data.

Purdue Pegboard Score

The participants' average score as a whole was significantly lower than normative data for the PPT. One sample t-tests were conducted on each subset of scores (Preferred hand, non-preferred hand, and both hands) to determine if there was a statistically significant difference between the PPT scores from this study's participants, and normative data. In the preferred hand score, students scored significantly worse (M = 14.25, SD = 1.88) compared the normative data (M = 16.13, Lafayette Instrument Company, 2015) , t (95) = -9.80, p = < .05. In the non-preferred hand score, students scored significantly worse (M = 13.36, SD = 1.60) compared the normative data (M = 15.59, Lafayette Instrument Company, 2015), t (95) = -13.69, p = < .05. In the score for both hands, students scored significantly worse (M = 11.55, SD = 1.71) compared the normative data (M = 13.175, Lafayette Instrument Company, 2015), t (95) = -9.30, p = < .05. There was no effect of music prime on the total PPT score, F (2, 96) = .234, p = .792. Refer to Table 1 for means and standard deviations across conditions. The pattern of results was identical when analyzing performance for only those who received the PPT directly after the music prime (e.g., PPT as the first task). This result shows that the rate of musical prime had no effect on processing speed.

Table 1

Purdue Pegboard Score across Music Conditions

Condition	Mean Score	Standard Deviation

Slow (*n* = 30)	38.90	4.08
Fast (*n* = 32)	39.59	4.49
Control (*n* = 34)	39.00	4.48

Reading Rate

The participants' average reading rate average was worse when compared to the normative data for the NDRT. In the reading rate score for the NDRT, students read significantly slower (*M* = 224.74, *SD* = 65.86) compared the normative data (*M* = 238.31, Brown et al., 1993), *t* (95) = -2.00, *p* = .048. There was no effect of music prime on the NDRT reading rate score, *F* (2, 96) = .261, *p* = .771. Refer to Table 2 for means and standard deviations across music conditions. The result pattern was identical when analyzing performance for only those who received the NDRT directly after the music prime. This result shows that rate of prime did not influence reading rate.

Table 2

Reading Scores across Music Conditions on the Nelson Denny Reading Test

Condition	Mean Score	Standard Deviation
Slow (*n* = 30)	226.53	68.32
Fast (*n* = 32)	218.03	56.11
Control (*n* = 34)	229.47	65.86

Comprehension Score

The participants' average comprehension score was better on the NDRT, (*M* = 52.77, *SD* = 13.92) when compared the normative data (*M* = 48.50, Brown et al., 1993), *t* (95) = 3.007, *p* =

.003. There was no effect of music prime on the NDRT comprehension score, F (2, 96) = .213, p = .808. See Table 3 for means and standard deviations across music conditions. The pattern of results was identical when analyzing performance for only those who received the NDRT directly after the music prime. This result indicates that rate of prime did not influence reading comprehension.

Table 3

Comprehension Score across Music Conditions on the Nelson Denny Reading Test

Music Condition	Mean Score	Standard Deviation
Slow (n = 30)	52.73	11.39
Fast (n = 32)	51.63	15.83
Control (n = 34)	53.88	14.34

Reading Rate and Comprehension

A Pearson Correlation was run to analyze the relationship between reading rate and comprehension scores on the NDRT. There was a positive correlation between Reading Rate and Comprehension, r = .567, p < .001, indicating that a faster reading rate is related to better scores on the comprehension portion of the NDRT.

Discussion

The aim of the current study was to see if music rate priming had an effect on processing speed and reading. This study also investigated if reading rate was related to reading comprehension. The results of this study show that the music prime had no effect on processing speed, reading rate, or reading comprehension. This could suggest that there is no domain general temporal processing mechanism. However, these results replicate previous results of the relationship between reading rate and comprehension being positively correlated.

Because the music prime did not affect the scores on the Purdue Pegboard Task (PPT), this could suggest multiple things. First, this may be because there was not a strong enough prime. In the priming study done by Ilie and Thompson (2011), they investigated how the speed (fast or slow), pitch (high or low), and intensity (loud or soft) of music affected processing speed and creativity, and found that slow music leads to slow processing speed on the routine task. The current study only manipulated the speed of the music and kept intensities and pitch the same with both the fast and slow conditions. Their prime was stronger because it was confounded with other factors, such as emotion, so it is possible that rate was not a contributing factor in their study. Ilie and Thompson (2011) measured felt emotion, which, when listening to something more upbeat or happy, can cause arousal, leading to a participant to have a better score on a processing speed task (Bottiroli et al., 2014). Their prime was also seven minutes in length (instead of three minutes), which would also contribute to the strength of their prime. It is believed that the strength of the prime could have been the problem in the current study because other research (Jungers & Hupp, 2009; Jungers, Hupp, & Dickerson, 2016; Kallinen, 2002) has found an effect of music primes. The music in the other studies was played at the same time, was confounded with emotion, and was longer which all led to stronger effects of prime. Future research should assess for felt emotion to see if arousal is a factor in influencing processing or reading speed instead of the rate of prime itself.

Another possible suggestion for the lack of priming effects could be that the PPT was not an appropriate measure of general processing speed. The PPT was originally used as a motor speed task, and later started being used as a processing speed task for a small handful of studies.

Although the PPT is generally used for motor dexterity measurement, there is a positive correlation between motor dexterity and processing speed, suggesting that the PPT would have initially been a good measure of processing speed (Ebaid, Crewther, MacCalman, Brown, & Crewther, 2017). The effect of music primes may be specific to other types of non-motor processing tasks. Future research should use a different measurement for processing speed, and assess other types of processing.

Future research should also look at how music primes affect oral reading (out-loud), or silent reading (in the mind) due to the different measures of accuracy and comprehension (Van de Boer, Van Bergen, & De Jong, 2014). With orally based reading, comprehension is assessed using oral reading rate and accuracy (Tranin, Hiebert, & Wilson, 2015), whereas, silent reading does not measure reading accuracy, which allows for less concentration on the pronunciation of the words (Schimmel & Ness, 2017), and involves less work with simultaneous and demanding tasks. This allows for more cognitive resources to be used on comprehension of a text (Hale, Hawkins, Schmitt, & Martin, 2011; Schimmel & Ness, 2017). When reading silently, studies show that reading speed is faster, and recall of the text is better when compared to those who read orally (Schimmel & Ness, 2017), but the current study shows that music primes do not affect silent reading speed. Previous research has shown that music primes affect language production (Jungers & Hupp, 2009; Jungers et al., 2016), which suggests a music prime may affect oral reading differently than it affects silent reading.

These results support current research that states a faster reading rate is correlated with better reading comprehension, but the results do not support previous research showing that music primes affect processing speed. Based on this research, we can suggest that listening to music before completing a task may not have a negative effect on the task at hand. This information can be used for future research when investigating the reading process and the differences of how music primes affect reading. Even though this research did not find what was expected, it has contributed to previous research on music primes by showing what does not work, and can help to influence future research with music primes. Although priming is a largely studied effect, there is still much to be explored in the effects of music priming on cognition.

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Appendix

Participant Demographic Information

In order to determine whether the results of our study apply to the general population or only to a specific subset, we ask that you take a few minutes to complete the following information. This information is for descriptive purposes only and will remain strictly confidential. Please do not put your name on this form. We appreciate your help and your willingness to cooperate in our research. Thank you.

AGE: ________ SEX: _____ Male _____ Female HANDED: _____Left_____Right

RACE/ETHNICITY:
_____ White/Caucasian
_____ Black/African-American
_____ Hispanic
_____ Middle Eastern
_____ Multi-racial
_____ Other (Please Specify) ____________________

EDUCATION STATUS:
Year in College: ___________ Major: ______________ GPA: __________

Do you have a vision problem? _____ YES _____ NO

If yes, Has it been corrected (Glasses/contacts, surgery, etc.)? ____YES _____NO

Do you have a hearing problem? _____ YES ______ NO

If yes, Has it been corrected (hearing aids, etc.)? ______YES _____NO

Do you have any attentional issues such as Attention-Deficit/Hyperactivity Disorder (ADHD or ADD)?
_____ YES ______ NO

If yes, Are you currently being treated for these issues? _____YES _____NO

Have you experienced a head injury in which you lost consciousness for several minutes or longer?
_____YES ______ NO

Is English your first language? _____ YES _____ NO
If no, what is your first language? _______________________

What was the purpose of this study?